Analysis of the GMI/CoSMIR Microwave Polarization Data for Ice Crystal Modeling

Xiping Zeng[1,2], Gail Skofronick-Jackson[2], Lin Tian[2,3], Amber E. Emory[2], Williams S. Olson[2,4], Rachel A. Kroodsma[2,5]

[1] US Army Research Laboratory [2]NASA GSFC [3]Morgan State University [4]University of Maryland Baltimore County [5]University of Maryland College Park

1. Motivation

GPM Microwave Imager (GMI) measures the intensity of radiation at high frequencies (e.g., 166 and 183 GHz). Its polarization data (e.g., 166V, 166H) can be used to analyze the distribution of ice crystal properties, such as ice crystal shape (Skofronick-Jackson et al. 2008). Here the data and ice crystal modeling are used to explore the mechanism of ice crystal growth .

2. Field Campaign Data (MC3E)

CoSMIR (the Conical Scanning Millimeter-wave Imaging Radiometer) and Doppler radar abroad the NASA ER-2 aircraft were used to measure clouds in the MC3E (Midlatitude Continental Convective Clouds Experiment). Their data are analyzed, or

- CoSMIR polarization data at 165.5 GHz
- Doppler radar reflectivity at Ku band

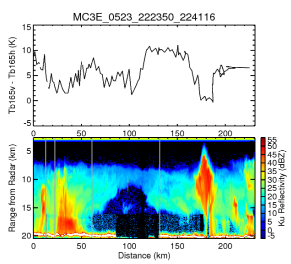


Fig. 1 Vertical cross section of the radar reflectivity from HIWRAP Ku-band measurements (bottom) and the corresponding polarization at 165.5 GHz obtained from the CoSMIR conical scan at nadir (top). The observations were taken by the NASA ER-2 aircraft from 2223 to 2241 UTC 23 May 2011 during MC3E.

Figure 1 shows that the polarization is strong over stratiform clouds, which suggests that the ice crystals near cloud top prefer a horizontal orientation.

3. Coincident Data of GMI and CloudSat

GMI and CloudSat, just like CoSMIR and airborne radar, measure microwave polarization and radar reflectivity, respectively. Their coincident data are analyzed in Fig. 2, which are

- GMI data at 166 GHz
- CloudSat radar reflectivity

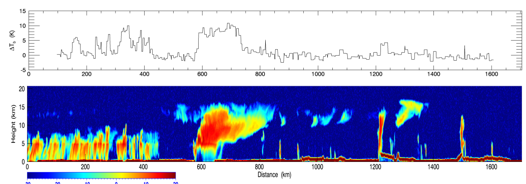


Fig. 2 Vertical cross section of CloudSat radar reflectivity (bottom) and GMI polarization difference at 166 GHz along the same CloudSat track (top) when both CloudSat and GPM flew over the Amazon at 18:06:52 UTC 13 November 2014.

4. Statistics of GMI and CloudSat Data

The coincident data of GMI and CloudSat over one and half year have been analyzed statistically with categories of

- Four cloud thickness: deep-convective (>20 dBZ), thick (between 5 and 20 dBZ), thin (between 5 and -20 dBZ) and extremely thin (<-20 dBZ)
- Two underlying surfaces: land, sea
- Three zones: tropics (latitude <25°), mid-latitudes (between 25 and 50°) and high latitudes (>50°)

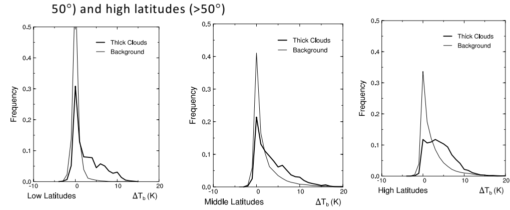


Fig. 3 Frequency of the GMI polarization difference ΔTb at 166 GHz over land for columns with the maximum radar reflectivity between 2 and 20 dBZ (thick) and between -20 and 5 dBZ (thin lines; referred to here as background) in the low (left), middle (middle) and high latitudes (right).

Figure 3 exhibits a positive contribution of clouds (or horizontally-oriented crystals), supporting the results in Figs. 1 and 2.

5. Ice Crystal Modeling

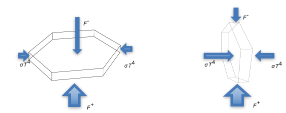
A bin model of ice crystals is developed to simulate ice crystal properties (i.e., ice crystal size, shape and orientation) against GMI data. The model uses

- **Macroscope radiation ratio**

$$\eta_z = \frac{F^+ + F^-}{2\sigma T^4}$$

* *F^+ and F^- represent the upward and downward fluxes of infrared radiation, respectively; T atmospheric temperature; σ the Stefan-Boltzman constant.*
* ***$\eta_z < 1$ near cloud top.***

- **Different radiation budgets for different orientations**



Ice crystals with different orientations (or sizes, shapes)
- receive different upward and downward radiative fluxes,
- possess different temperatures, and consequently
- have different saturation water pressure around them.

Spectra evolution of ice crystals with different orientations

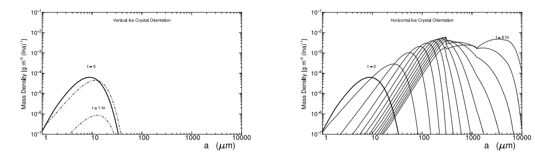


Fig. 4 Evolution of the mass density dM(lna)/dlna versus the half crystal size a for the vertical- (left) and horizontally-oriented (right) plate crystals in a simulation with η_z=0.5. The thick lines denote the initial spectra and the time interval between lines is 30 minutes.

- **Size evolution of spherical and plate ice crystals**

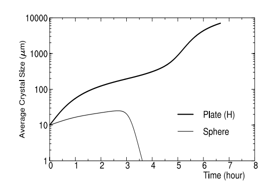


Fig. 5 Average crystal size versus time in a simulation with spherical and horizontally-oriented plate crystals (half by half), where η_z=0.5. The thick and thn lines represent the average size of horizontally-oriented plate crystals and the average radius of spherical ice crystals, respectively.

Figs. 4 and 5 show that horizontally-oriented ice crystals survive while vertically-oriented (or spherical) ones disappear when η_z<1.

6. Conclusions

- A bin model is developed to simulate the evolution of ice crystals in size, shape and orientation. It shows that horizontally-oriented ice crystals grow faster than the vertically-oriented (or spherical) ones when η_z < 1.
- The GMI polarization and other data support the model prediction, indicating that the radiation effect on microphysics play an important role in the global water cycle.

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